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(54) Optical disc apparatus

(57) The present invention provides an optical disc apparatus for simultaneously producing information signals from a plurality of tracks formed concentrically or spirally on an optical disc by irradiating a laser beam over the plurality of tracks so as to extend in a radial direction of the optical disc and detecting a reflected light beam therefrom. The apparatus comprises an optimum focus point detection device for generating a focus offset compensation signal responsive to a detection of the reflected light beam, and a plural-division photo-detector for outputting a reproduction signal by receiving the reflected light beam, wherein the optimum focus point detection device outputs the focus offset compensation signal by using the output signal outputted from the plural-division photo-detector.

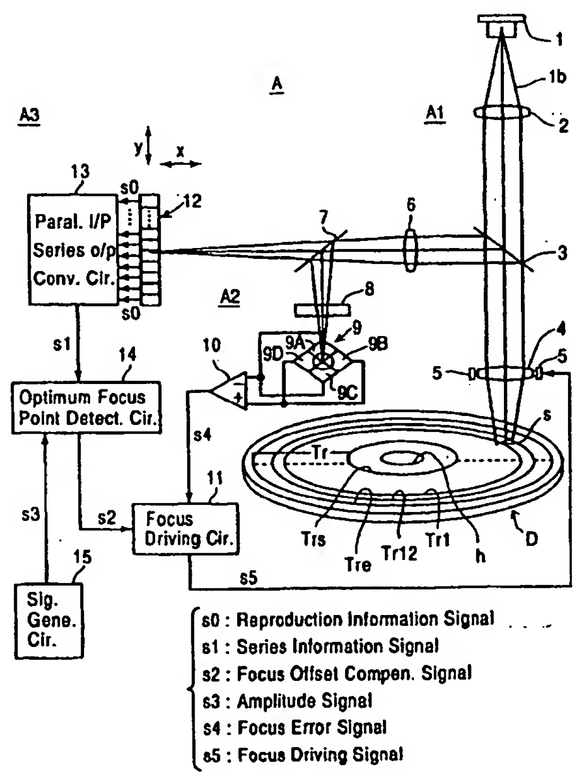

Fig. 1

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Specifically, in the ordinary optical disc apparatus mentioned above, the astigmatism optical system and the reproduction information signal detection optical system shares a common optical system, or both the systems are disposed close to each other. Here, the ordinary optical disc apparatus has an optical system as follows.

A laser beam emitted from a laser light source is irradiated on the recording track formed on the optical disc through a collimator lens, a semi-transparent mirror and an objective lens.

Thereby, the reflected light beam from the optical disc is again reflected by the semi-transparent mirror though the objective lens and impinges on the 4-division optical detector through the collecting lens. Here, a detection of the focus error is performed. Here, the collimator lens is generally used in common as a collecting lens, and the semi-transparent mirror may be disposed between the laser light source and the collimator lens. As a result, a focal length of the collimator lens is equal to a focal length of the collecting lens to the 4-division sensor, or the difference between their focal lengths, if any, is small.

On the other hand, in the optical disc apparatus capable of simultaneously reproducing the information signals from the plural recording tracks, the focal length of the collimator lens is greatly different from that of the imaging lens for collecting a light beam reflected by a semi-transparent mirror which is disposed along an optical path defined between the collimator lens to the objective lens, to the reproduction information signal detection sensor, as mentioned hereinafter.

Specifically, the optical system thereof is constructed as follows.

The light beam emitted from the laser light source is irradiated on the tracks formed on the optical disc through the collimator lens, the semi-transparent mirror and the objective lens. Thereby, the light beam reflected from the optical disc is reflected by the semi-transparent mirror through the objective lens, and the light beam is separated into two light beams by another semi-transparent mirror through the imaging lens (collecting lens), i.e., a light beam impinging on the astigmatism optical system and another light beam impinging on the reproduction information signal detection optical system.

More specifically, the focal length (fc) of the collimator lens is determined by an expansion of the light beam on the optical disc and an optical coupling efficiency from the laser light source to the objective lens, and is 2 to 5 times as long as the focal length (fo) of the objective lens. On the contrary, the focal length of the imaging lens (fi) is 30 to 50 times as long as that of the objective lens to allow minute pits to be projected on the photodetector having an area larger than that of the pits.

Lateral magnification of the optical system for giving astigmatism in the optical disc apparatus is:

$$m1 = fc/fo \qquad (1)$$

Lateral magnification of the reproduction information signal detection optical system is:

$$m2 = fi/fo \qquad (2)$$

When an environmental temperature changes, the length of each of sections forming the optical disc device linearly changes. At that time, in the reproduction information signal detecting optical system, the optimum focus point capable of obtaining the maximum output level of the reproduction information signal is deviated from a state where the environmental temperature is not changed.

On the other hand, when noting each sensor in the astigmatism optical system and the reproduction information signal detecting optical system, there is a just focus position on the optical disc to allow each sensor to output the maximum output level. It is desirable that the focus point after the change of the environmental temperature accords with the just focus position thereof, however, it does not accord therewith because of following reasons.

Specifically, change values in length from the respective sensors to the respective optimum focus points before and after the change of environmental temperature in the astigmatism and reproduction information signal detecting optical systems depend on longitudinal magnification.

Thus, each of the change values thereof varies in proportion to square of the lateral magnification m1, m2.

Further, the change values thereof vary in proportion to the focal length of the collimator lens (fc) and that of imaging lens (fi), respectively. Thus, when the lateral magnification m1 is not equal to the lateral magnification m2, it is not always possible to obtain the optimum focus point in the reproducing information signal detection optical system even when the optimum focus point in the 4-division sensor of the astigmatism optical system is obtained.

Accordingly, when detecting the focus point by the astigmatism method, the optimum focus point in the astigmatism optical system does not accord with the optimum focus point in the reproduction information signal detection optical system, resulting in a focus error (focus offset) between both sensors.

In the optical disc apparatus in the prior art, as the difference between the lateral magnifications m1 and m2 is small, a large focus error is not generated. However, in the the optical disc apparatus wherein the astigmatism optical system and the reproduction information signal detection optical system are placed apart from each other, there is generated a large focus error between both sensors by the change of environmental temperature because of the large difference between the lateral magnifications m1 and m2.

Further, generally, the focus operation point is optimized so that the output of the reproduction information signal becomes maximum. However, in parallel repro-

detector are converted into a serial information signal by being added in series. Then, an optimum focus point in the reproduction information detection optical system is determined by using the maximum output level of the serial information signal.

Specifically, a focus offset voltage (focus offset compensation signal) is produced so as to eliminate the focus offset defined as a deviation of the optimum focus point of the astigmatism optical system (focus detection optical system) from the optimum focus point where the output level of the serial information signal is maximum. This offset voltage is supplied to the astigmatism optical system to allow the focus error signal of the astigmatism optical system itself to control the optimum focus point of the reproduction information detection optical system by being superimposed to the focus error signal thereof. Thus, the reproduction information signal in parallel i.e., an optical image, can be always reproduced at the optimum focus point in the present invention.

Thereby, for instance, upon reproducing the signal from the optical disc having double recording layers, it is possible to securely eliminate the influence of unnecessary optical interference from the off tracks. This enables to provide the optical disc capable of reproducing the signals from the plural tracks at the optical focus point irrespective of the environmental change and irrespective of the optical disc having the double recording layers or the sole recording layer.

Next, the description is given of the optical disc apparatus of the present invention referred to Figs. 1 to 7.

Fig. 1 is a schematic view for explaining a construction of the optical disc apparatus of the present invention;
Fig. 2 is a schematic view for explaining an operation of a plural-division photo-detector and a parallel-input serial-output converting circuit;
Fig. 3 is a graph for explaining detected signal which is obtained by envelope-detecting the reproduction information signal output from the plural-division photo-detector;
Fig. 4 is a graph for explaining an operation of an optimum focus driving detecting circuit;
Fig. 5 is a graph for explaining an optimum focus point;
Fig. 6 is a schematic view for explaining a reproduction operation order when the reproduction is performed by using the optical disc apparatus of the present invention; and
Fig. 7 is a graph for explaining an operation for transferring the focus driving point to the optimum focus point by using a focus offset compensation signal.

The optical disc apparatus of the present invention is explained in the following order.

(1) Construction of the optical disc apparatus A of the present invention.

(1-1) Construction and an operation of an irradiation optical system A1
(1-2) Construction and an operation of a focus detection optical system A2
(1-3) Construction and an operation of an optical image reproduction optical system A3

(2) Operation of the optical disc apparatus of the present invention

(1) Construction of the optical disc apparatus A of the present invention

As shown in Fig. 1, the optical disc apparatus A of the present invention comprises an irradiation optical system A1, a focus detection optical system A2 as an astigmatism optical system and an optical image reproduction optical system A3 as the reproduction information signal detecting optical system.

In Fig. 1, a reference character D denotes an optical disc, Tr tracks (all the tracks Trs to Tre from an inmost track to an outmost track), Trs the inmost track formed concentrically or spirally at an inmost circumference on the optical disc D, Tre the outmost formed concentrically or spirally at an outmost circumference on the optical disc D, Tr1 to Tr12 plural tracks from which information signals are being reproduced, and h a center hole.

As a matter of convenience, the description is given of the optical disc D having a sole recording layer at a depth of 0.6 mm or 1.2 mm therein on which plural tracks are concentrically or spirally formed.

Another example, it is possible to employ the optical disc D having double recording layers at a depth of 0.6 mm and a depth of 1.2 mm therein, respectively. In this case, it is also possible to obtain such an optical image that an image obtained based on the reflected light from a series of bits of each track and an image obtained based on the reflected light from vacancy (land) between the tracks are successively disposed in parallel in the optimum focus condition by controlling the focus of the light beam irradiated at one recording layer to be reproduced so as to obtain the reproduction optical image (reproduction information signal) in the optimum focus condition, as well as in the case of the optical disc having the sole recording layer.

<u>(1-1) Construction and an operation of an irradiation optical system A1</u>

The irradiation optical system A1 is composed of a surface illuminant 1, a collimator lens 2, a semi-transparent mirror 3, an objective lens 4 and a focus actuator 5.

The surface illuminant 1 is not one for irradiating a laser beam of a single transverse mode but one for irra-

ing signal s5 to the focus actuator 5 of the irradiation optical system A1 mentioned in the foregoing, wherein the focus driving signal s5 is obtained by superimposing the focus offset compensation signal s2 inputted from the optical image reproduction optical system A3 to the focus error signal s4 of the focus detection optical system A2.

As a result, the focus actuator 5 can perform the control of the objective lens 4 (the control of focus position) responsive to the level of the focus driving signal s5 which is related to both the focus detection optical system A2 and the optical image reproduction optical system A3.

Here, the focus error signal s4 outputted from the comparator 10 of the focus detection optical system A2 is a focus position error signal for mainly controlling the objective lens 4, and has a wide band range.

Next, the description is given of the case where the circumferential temperature is changed even when both the focus detection optical system A2 and the optical image reproduction optical system A3 are thoroughly controlled.

As shown in Fig. 7, the focus driving point in the focus matching state in the focus detection optical system A2 is located at a position of f1. On the other hand, when the focus driving point is located at the position f1, the level (sharpness level) of the serial information signal s1 outputted from the parallel input serial-output converting circuit 13 of the optical image reproduction optical system A3 corresponds to a sharpness level s1a which does not show the maximum sharpness level s1b. In order to obtain the serial information signal s1 having the maximum sharpness level s1b, the focus driving point f1 has to be transferred to the optimum focus point f2 so as to coincide therewith. Thus, it is necessary to eliminate the focus offset fof defined as a deviation of the focus driving point f1 from the optimum focus point f2.

The optimum focus driving point detection circuit 14 prevents the optimum focus point f2 from deviating to the focus driving point f1 by applying the focus offset compensation signal s2 to the focus driving circuit 11.

As a result, even when the focus offset compensation signal s2 is superimposed on the focus error signal s4, the focus driving signal s5 itself outputted from the focus driving circuit 11 is not adversely affected.

In other words, the focus driving signal s5 from the focus driving circuit 11 has both the focus error signal component capable of controlling the objective lens 4 at a real time and the focus matching point detection signal component capable of controlling the objective lens 4 responsive to the optical image in the focus matching state at a large period, and both the components have been detected in a good state in the focus detection optical system A2 and the optical image reproduction optical system A3.

(1-3) Construction and an operation of an optical image reproduction optical system A3

The optical image reproduction optical system A3 is composed of the condenser lens 6, the semi-transparent mirror 7, the plural-division photo-detector 12, the parallel-input serial-output converting circuit 13, the optimum focus driving point detection circuit 14 and a signal generating circuit 15.

The focus point and the setting position of the condenser lens 6 are determined so that the reflected light beam passing through the condenser lens 6 is collected on the light detection cells of the plural-division photo-detector 12. On the plural-division photo-detector 12 the reflected light beam passing through the semi-transparent mirror 7 is irradiated. The plural-division photo-detector 12 is composed of plural photo-detection cells disposed in a network state, and is made of, for instance, CCD (Charge Coupled Device). As another example of the plural-division photo-detector, it is possible to employ a plural-division photo-detector where the detection cells are disposed in a line.

Here, for simplicity, only one line of photo-detection cells is shown in Figs. 1 and 2 as the plural-division photo-detectors 12. Actually, such photo-detection cells are disposed in a row direction x and in a column direction y. The reproduction information signal s0 represents an output reproduced from one line of plural cells of the plural-division photo-detector 12. When the plural-division photo-detector is composed of plural lines of cells, the reproduction information signal s0 is an output processed responsive to the time while the light beam passes through the plural lines of cells.

The reflected light beam passing through the semi-transparent mirror 7 is simultaneously received in parallel by all the photo-detection cells of the plural-division photo-detector 12, and all the optical image in the range irradiated with the optical spot s (i.e., the optical image based on the reflected light beam from the pit rows forming the track on the optical disc D as well as the optical image based on the reflected light beam from the vacancy (land) between the tracks) is divided into plural segments of the optical image corresponding to one line of the photo-detection cells, and each signal outputted from each of the plural segments of the optical image is supplied in parallel to the parallel input serial-output converting circuit 13 as the optical detection signal (reproduction information signal) s0.

The reproduction information signal s0 is divided into two branches, one passing through the parallel input serial-output converting circuit 13 and the other not passing therethrough. The reproduction information signal s0 not passing through the circuit 13 is detected in parallel by a reproduction processing circuit (not shown), and is taken out as the reproduction information signal therefrom.

On the other hand, the reproduction information signal s0 passing therethrough is envelope-detected

tracks.

Next, the description is given of the operation of a new focus servo system including the optical image reproduction optical system A3.

The amplitude of the reproduction information signal s0 detected from the plural-division photo-detector 12 is detected (or sampled) by the envelope detecting circuit 13A.

And, the envelope detecting circuit 13A outputs in parallel the parallel envelope detection signal to the parallel-input serial-output converting circuit 13. And, the serial information signal s1 outputted from the parallel-input serial-output converting circuit 13 is outputted as a function with respect to a diameter direction of the optical disc D. The point where the amplitude of the series information signal s1 is maximum, is the best point of the focus (the focused point of the optical image), and this amplitude corresponds to the sharpness. The maximum level of the sharpness is the optimum focus point.

Fig. 5 is a graph showing that the optimum focus point corresponds to the case where the sharpness level (the level of the serial information signal s1) is maximum.

In the optimum focus driving point detection circuit 14, the peak point (maximum level) of the serial information signal s1 is found out by changing the operating point of the focus, and the compensation operation is performed by causing the focus offset compensation signal s2 to be inputted to the focus driving circuit 11 so that this point is made to be the operating point (the optimum focus point). If the compensation of the operating point, that is, the setting of level of the focus offset compensation signal s2, is needed only one time per one reproduction of the signal from the optical disc, the series of operations may be performed only one time.

Further, in the focus offset of the optical disc having the double recording layers, it is better to compensate in real time the change of operating point caused by the environmental change because the amount of change depends on the thickness between the double layers. For that purpose, the change of the sharpness of the optical image in the diameter direction of the optical disc is detected by periodically varying the operating point of the focus servo slightly. Thus, it is possible to perform the real time operation by generating the focus offset compensation signal by using the detected signal.

Specifically, the signal generating circuit 15 periodically, intermittently or continuously, outputs an amplitude signal having a predetermined amplitude and superimpose it to the focus offset compensation signal s2 outputted from the optimum focus driving point detectioncircuit 14.

Further, in order to compare the modulation degree of the serial information signal s1, the signal generating circuit 15 preliminarily provides the amplitude signal s3 to the optimum focus driving point detection circuit 14. The focus offset compensation signal s2 periodically, intermittently or continuously superimposed with the amplitude signal s3 gives fluctuation to the focus driving signal s5 outputted from the focus driving circuit 11 responsive to the minute fluctuation due to the amplitude signal s3.

Thus, the focus driving signal s5 varies in a minute level. As a result, a minute change of the focus is given to the focus servo system (the objective lens 4, the semi-transparent mirror 3, the condenser lens 6, the semi-transparent mirror 7 and the optical focus driving point detection circuit 14, the focus driving circuit 11, the focus actuator 5 and the objective lens 4).

By the effect of the minute change, the serial information signal s1 to be inputted to the optimum focus driving point detection circuit 14 varies in a minute level (i.e., the serial information signal s1 is modulated by the amplitude signal s3). The optimum focus driving point detection circuit 14 detects the serial information signal having the maximum modulation by comparing the amplitude signal s3 with the serial information signal s1 (the detection of the maximum sharpness level is performed by the detection of the peak).

Thereby, the optimum focus driving point detection circuit 14 can generate the focus offset compensation signal s2 capable of making the sharpness level maximum. This point is the optimum focus point as shown in Fig.5.

Accordingly, it is possible to perform desired compensation operation by controlling the focus offset at real time.

As another peak detection method, there is one where the peak point is detected by using a fact that when the amplitude signal is modulated at the optimum focus point shown in Fig. 5, the frequency of the modulated amplitude signal becomes two times as high as that of the amplitude signal. Thus, this change of frequency can be detected by using heterodyne detect, resulting in the detection of the optimum focus point.

Next, the description is given of another preferable constructive example.

Here, a number of tracks to be read out simultaneously is made to be larger at least by two than the necessary number of tracks which is determined by a transfer rate in the optical disc device. Upon reproducing the signal from optical disc having spiral tracks such as CD or DVD, a track jump is indispensable at one revolution of the optical disc optical disc D. Thus, it is convenient to employ the reproduction method where the tracks are always reproduced in an overlapping state because of ceaseless reproduction.

Here, when the focus change is intermittently or periodically given in synchronization with the track jump just before or just after the track jump, upon reading out the information data, it is possible to detect the information data without the fluctuation of the focus.

In other words, the information signals corresponding to 12 tracks are simultaneously reproduced by the optical disc apparatus A of the present invention, and among them, the information signals corresponding to

signal s1 becomes maximum, and continues outputting the focus offset compensation signal 32 having the detected optimum level until next detection operation of the optimum focus driving point.

In other words, in the optimum focus driving point detection circuit 14, the peak point is detected by changing the focus operation point, and the offset voltage is applied to the focus driving circuit 11 so that the peak point is made to be the operation point of the focus servo. If the compensation of the operating point is needed to be detected only one time per one reproduction of the signal from the optical disc, the series of operations may be performed only one time.

As mentioned above, according to the present invention, it is possible to simultaneously reproduce the information signals from the plural tracks formed on the optical disc D in the optimum focus condition.

As another example, when the astigmatism in the astigmatism method is performed by using the same sensor employed for both the astigmatism detection (focus detection) and the signal detection, the occurrence of astigmatism is performed in the projection optical system because aberration has to be suppressed in the optical system from the objective lens from the sensor.

Specifically, it is possible to develop the astigmatism by disposing a cylindrical lens close to the collimator lens. In this case, it is possible to construct the plural-division photo-detector 12 and the 4-division photo-detector 9 on the same photo-detector by surface division.

According to the optical disc apparatus of the present invention, the apparatus is constructed so that the optical image is reproduced in the optimum focus condition by detecting the optimum focus point based on the intensity distribution of the reproduced optical image which is obtained being simultaneously reproduced from the plural tracks formed on the optical disc by using the plural-division photo-detector.

Thereby, it is possible to provide the optical disc apparatus capable of avoiding unnecessary interference light from the recording layer not to be reproduced irrespective of change of the environmental temperature, and always reproducing the signal from the tracks to be reproduced in the optimum focus condition by controlling the focus.

Needless to say, upon reproducing the signals from the optical disc having one recording layer, it is possible to provide the optical disc apparatus capable of avoiding unnecessary interference light irrespective of change of the environmental temperature, and always reproducing the signal from the tracks in the optimum focus condition by controlling the focus.

Claims

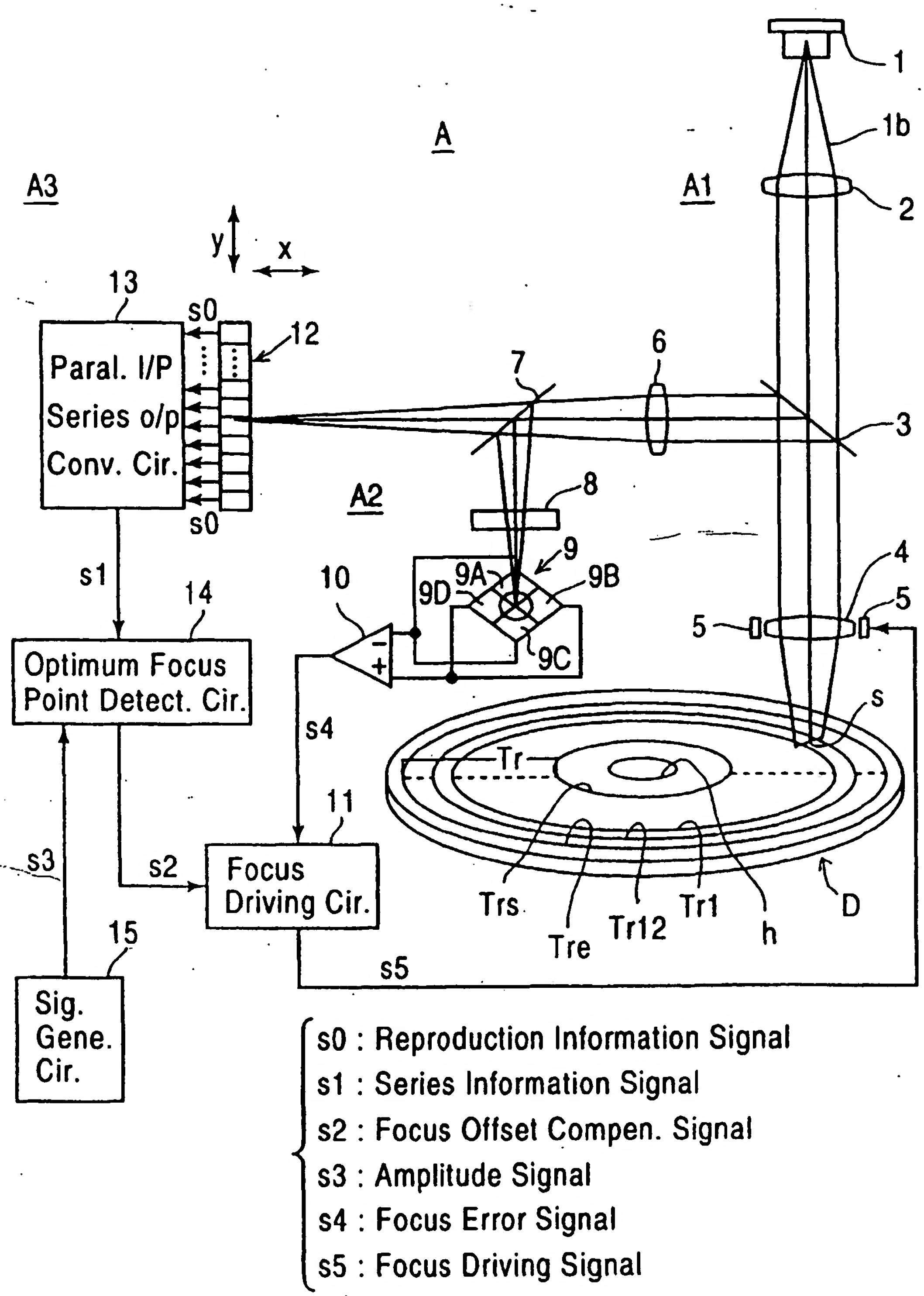
1. An optical disc apparatus for simultaneously reproducing information signals from a plurality of tracks formed concentrically or spirally on an optical disc by irradiating a laser beam over the plurality of tracks so as to extend in a radial direction of the optical disc and detecting a reflected light beam therefrom, the apparatus comprising:

    an optimum focus point detection means for generating a focus offset compensation signal responsive to a detection of the reflected light beam, and
    a plural-division photo-detector for outputting a reproduction signal by receiving the reflected light beam, wherein the optimum focus point detection means outputs the focus offset compensation signal by using the output signal outputted from the plural-division photo-detector.

2. An optical disc apparatus for simultaneously reproducing information signals from a plurality of tracks formed concentrically or spirally on an optical disc by irradiating a laser beam over the plurality of tracks so as to extend in a radial direction of the optical disc and detecting a reflected light beam therefrom, the apparatus comprising:

    focus control means for performing a focus control by using a focus driving point which is obtained responsive to the reflected light beam; and
    optimum focus point detection means for generating a focus offset compensation signal to change the focus driving point and outputting the focus offset compensation signal to the focus control means so as to obtain a maximum level of reproduction information signal, wherein the optimum focus point detection means comprises:
    a plural-division photo-detector for outputting a reproduction information signal in parallel by receiving the reflected light beam and;
    signal converting means for converting the reproduction information signal in parallel to a serial information signal to be outputted;
    signal generator means for generating an amplitude signal having a predetermined amplitude to be superimposed with the focus driving signal, and
    an optimum focus driving point detecting circuit for outputting the focus offset compensation signal by detecting an offset level to be compensated through an amplitude of the focus driving signal superimposed with the amplitude signal so as to obtain a maximum modulation of the serial information signal.

3. The optical disc apparatus as claimed in claim 2, wherein the optimum focus driving point detecting circuit detects the offset level of the focus offset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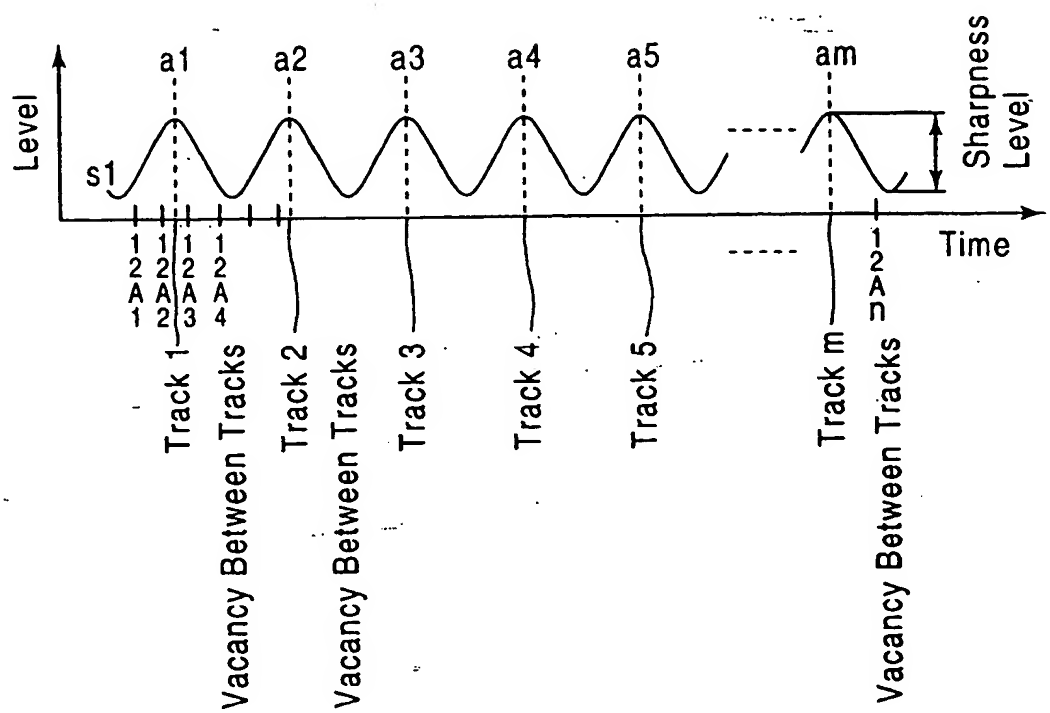
s0 : Reproduction Information Signal
s1 : Series Information Signal
s2 : Focus Offset Compen. Signal
s3 : Amplitude Signal
s4 : Focus Error Signal
s5 : Focus Driving Signal

Fig. 1


a1
a2
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a4
a5
am
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s1
Sharpness Level
Time
1/2 A1
1/2 A2
1/2 A3
1/2 A4
1/2 An
Track 1
Vacancy Between Tracks
Track 2
Vacancy Between Tracks
Track 3
Track 4
Track 5
Track m
Vacancy Between Tracks

Fig. 4

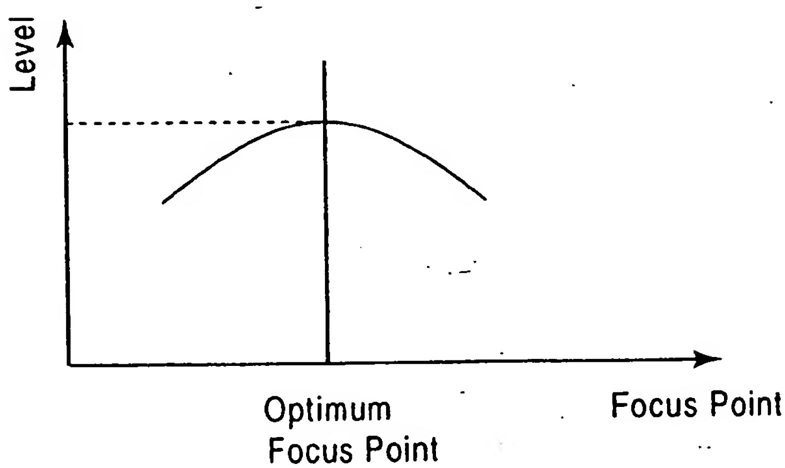
Level
Optimum
Focus Point
Focus Point

Fig. 5

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(54) **Optical disc apparatus**

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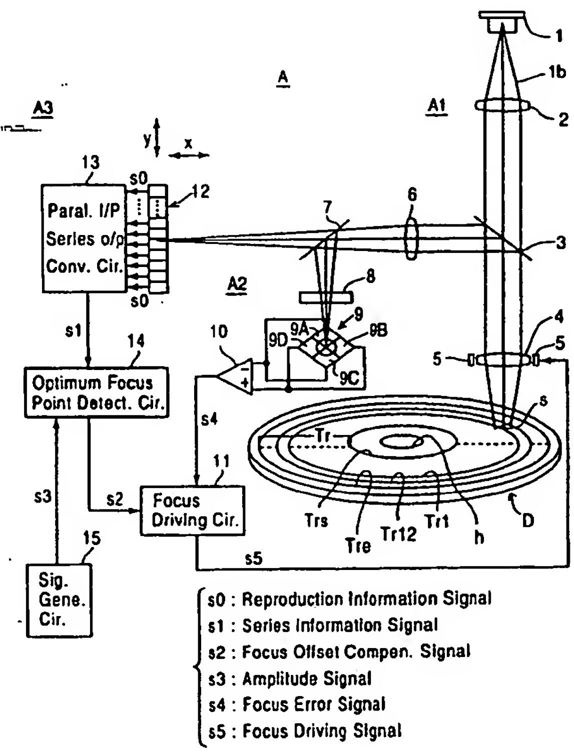

Fig. 1

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 98 10 3622

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